



Chromium Bio-Immobilization at the Hanford 100H Site: Geochemical Response to Slow Release Electron Donor

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<http://www-esd.lbl.gov/ERT/hanford100h/>

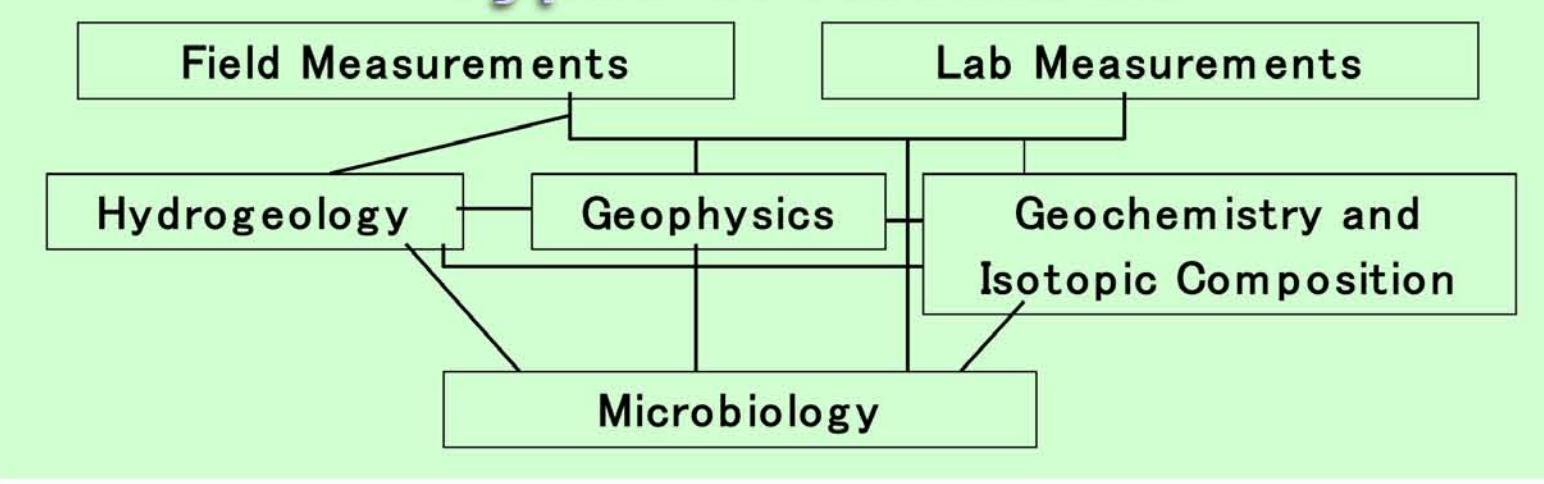
Hypothesis

Lactate (Hydrogen Release Compound—HRC™) injection into chromium contaminated groundwater through an injection well will cause indirect or direct bioreduction of chromate [Cr(VI)] and precipitation of insoluble species of [Cr(III)] on soil particles, probably catalyzed at oxide surfaces, at the field scale.

Objective

To carry out field investigations to assess the potential for immobilizing and detoxifying chromium-contaminated groundwater using lactate-stimulated bioreduction of Cr(VI) to Cr(III) at the Hanford Site's 100-H Area field site.

Types of Research

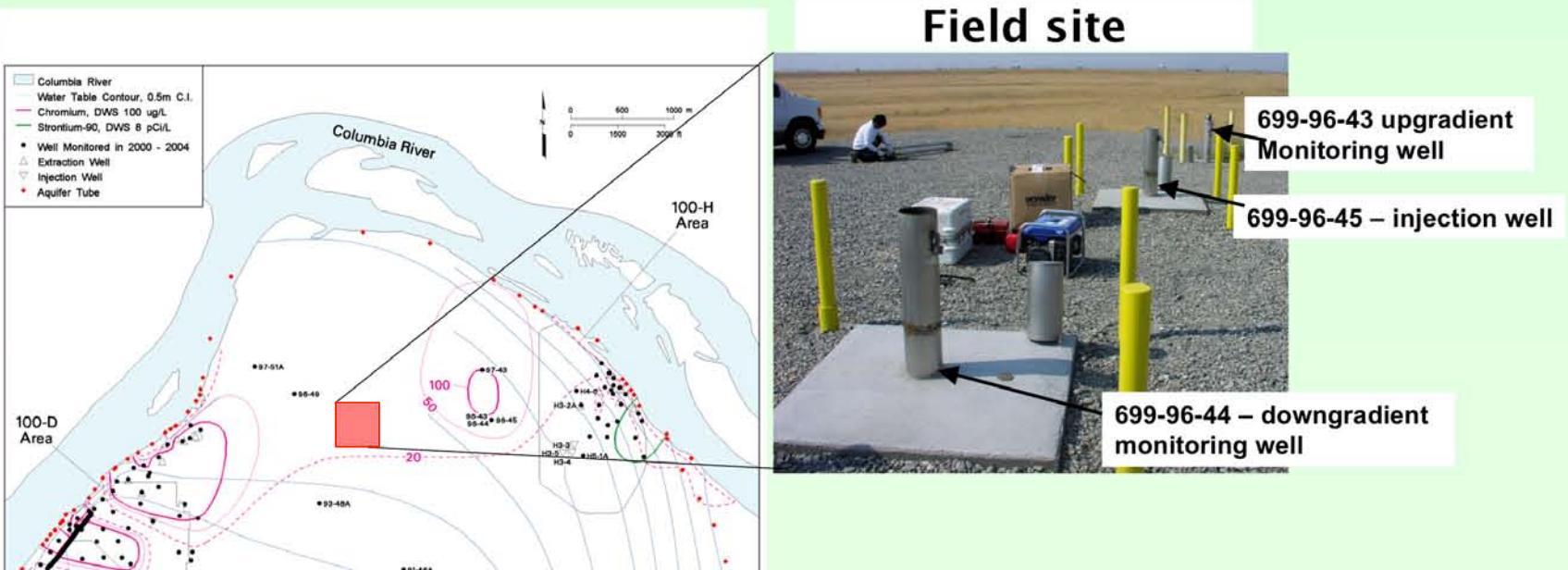


- Drilling, coring, and completion of two new 60 ft deep boreholes
- Development of a conceptual model of background conditions
- Microbial and lactate-induced laboratory and field studies
- Geophysical characterization
- Water sampling
- Hydraulic measurements

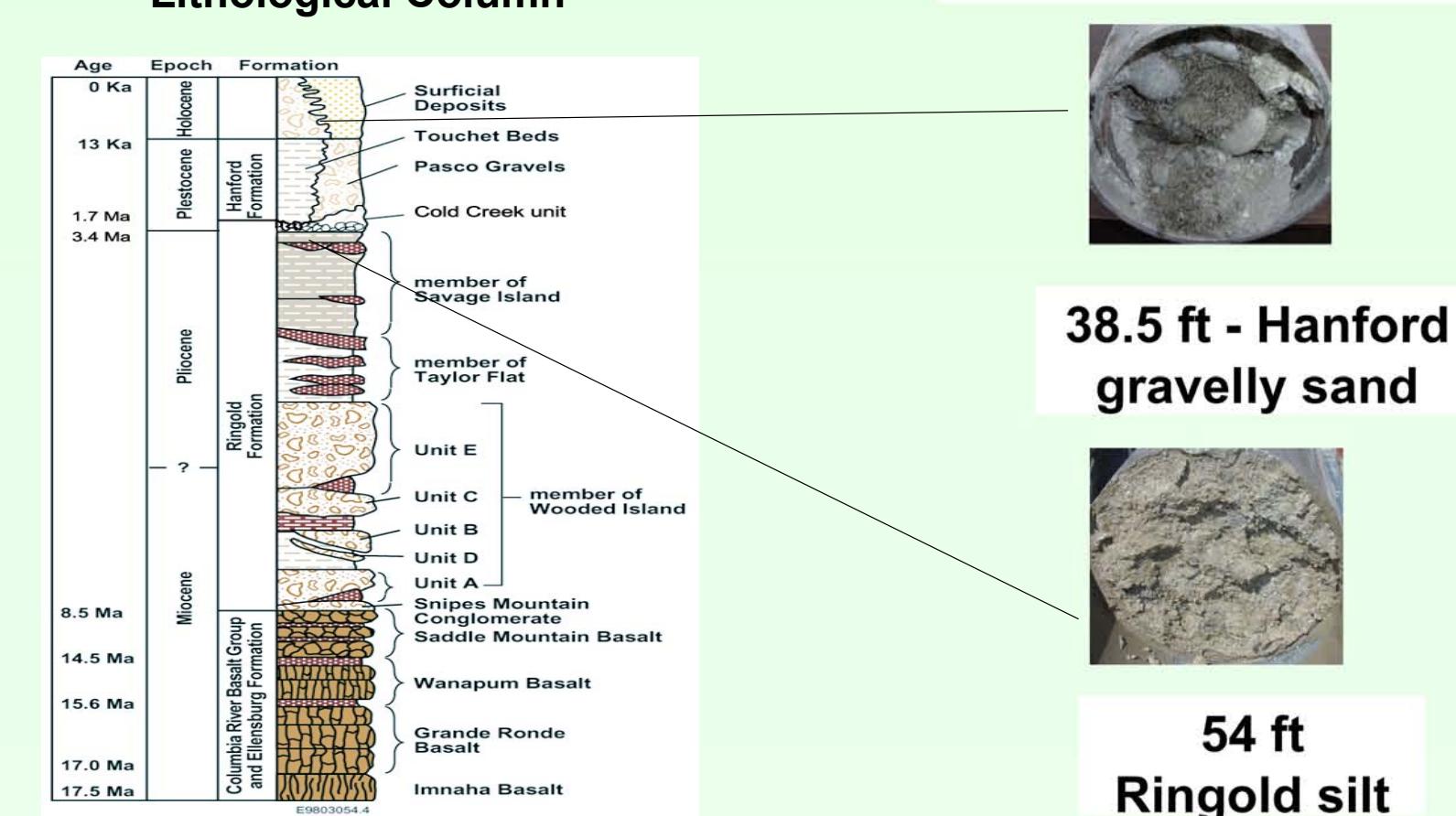


I. Background Geological, Hydrological, Geophysical, and Microbial Conditions at Hanford 100H

Chromium in groundwater at Hanford 100D area is source at Hanford 100H area

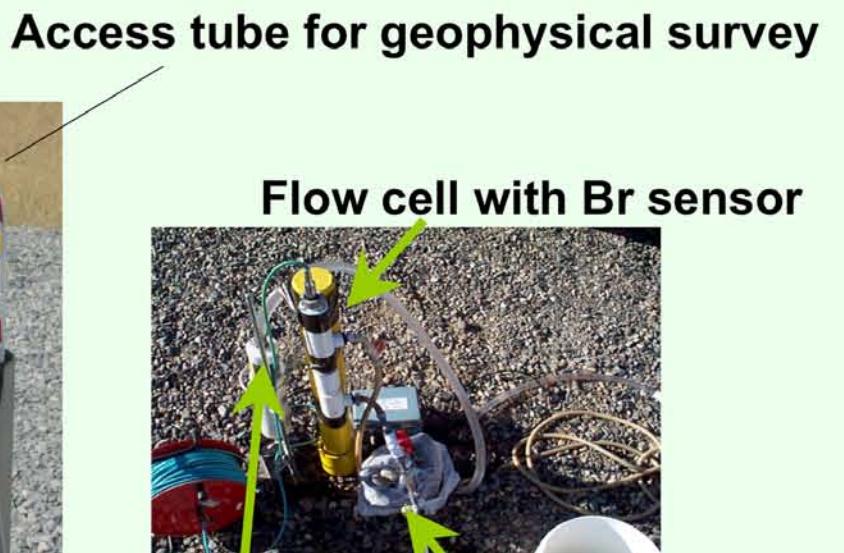


Cores (4 in. diameter)

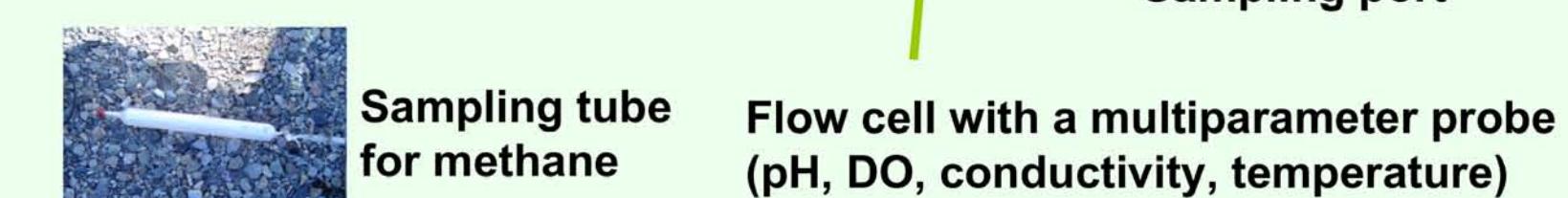


38.5 ft - Hanford gravelly sand

54 ft Ringold silt



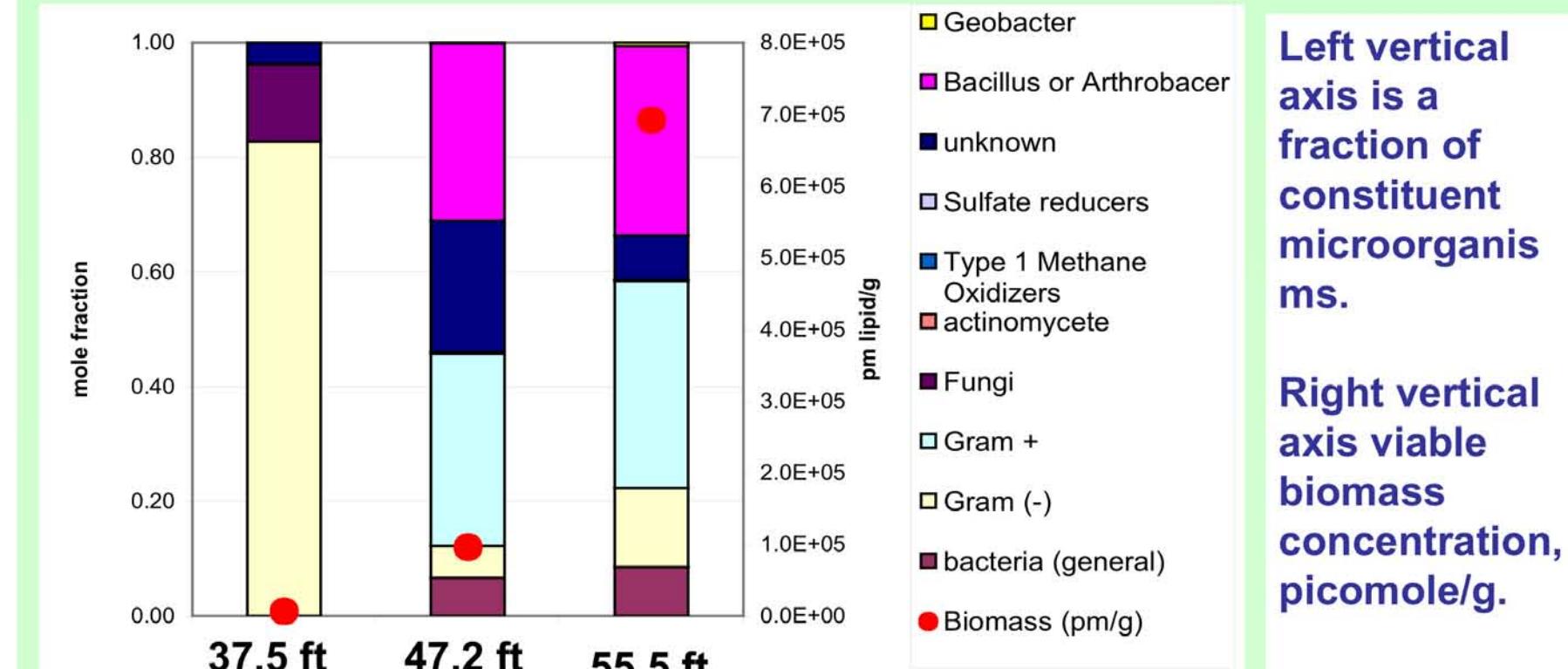
Groundwater sampling and packer inflation using argon gas



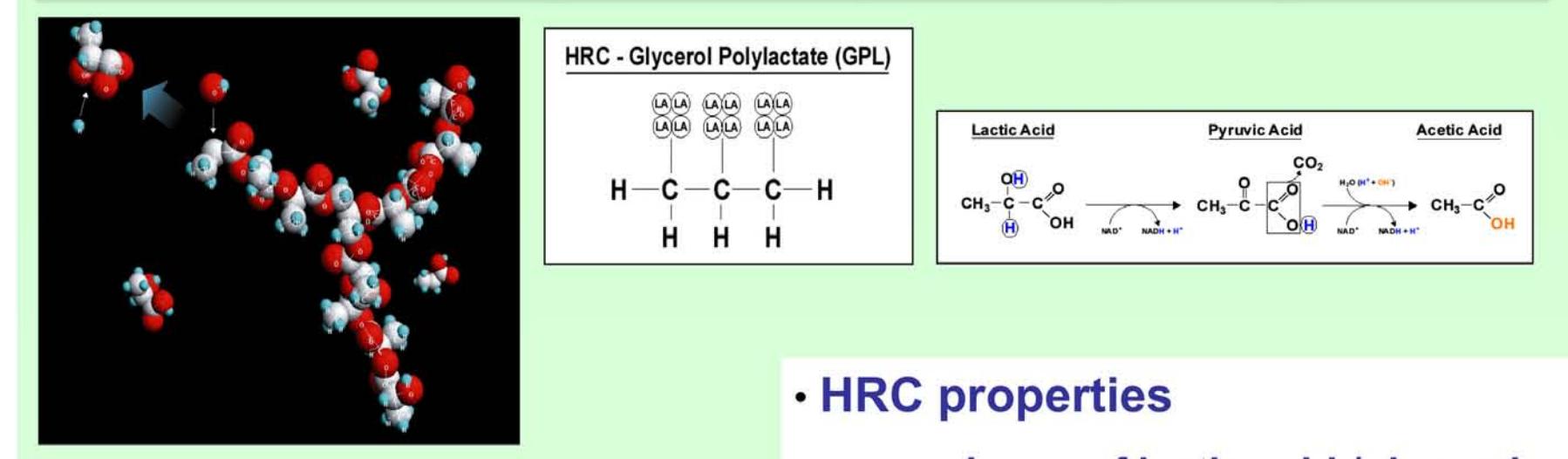
Microbial Analyses

- Phospholipid fatty acid analyses (PLFA)
- Terminal restriction fragment length polymorphism (T-RFLP) with primers for Fe and sulfate reducers, and nitrate dissimilatory reactions;
- Live/dead direct counts;
- TEA, ED, DOC, DIC, CO₂, O₂ Limiting nutrients, e.g., N, P, S, Fe;
- Nitrogen and oxygen isotope ratio; ⁵³Cr/⁵²Cr ratios
- Clone libraries
- 16S rRNA GeneChip
- Direct rRNA analysis by microarray
- Novel PCR independent analysis of microbial communities (Bacteria and Archaea)

Sediment Microbial Community from the PLFA Analysis of R2A Enrichment of Sediment Samples



II. Lactate/Polylactate (HRC™) Properties



HRC properties

- a polymer of lactic acid (glycerol polylactate)
- fermented by indigenous microorganisms to produce H₂ an electron donor
- in the subsurface, slowly releases lactic acid to stimulate anaerobic bacteria and ferment the lactic acid to gain carbon and energy

HRC, when injected into chromium contaminated groundwater:

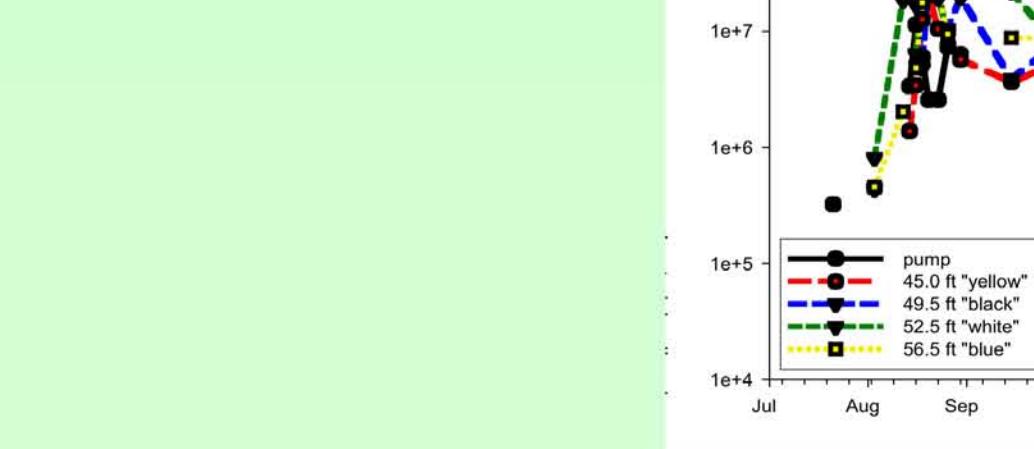
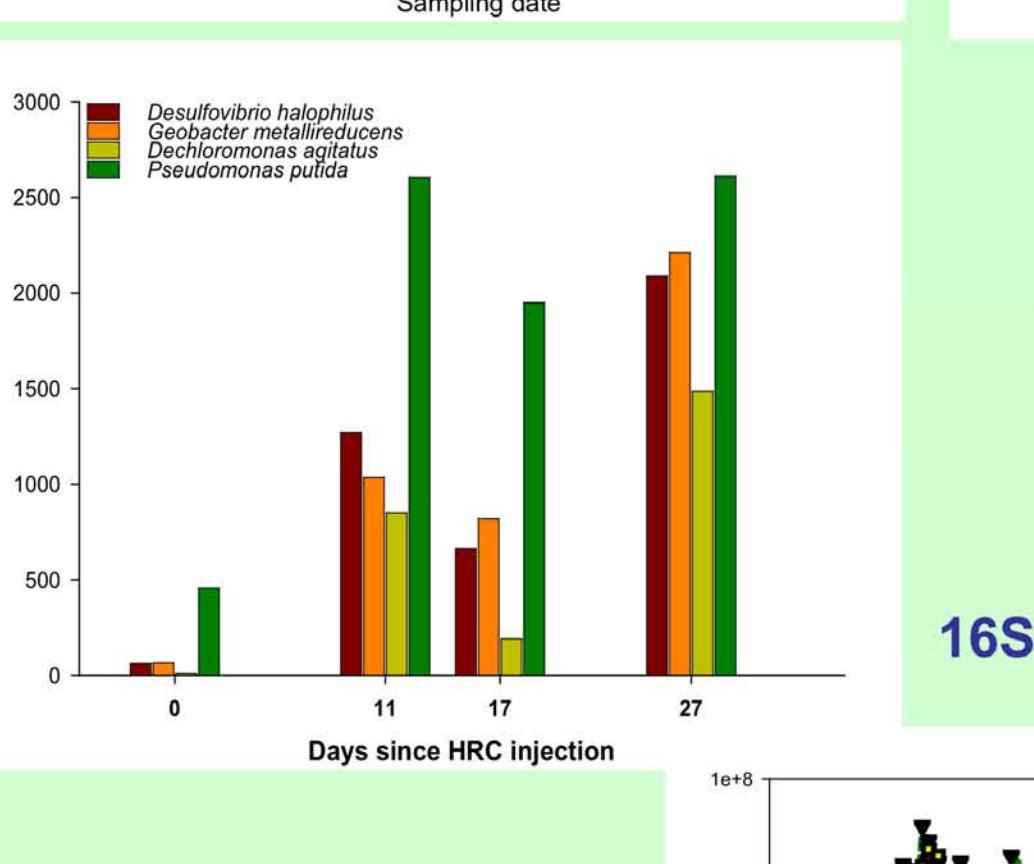
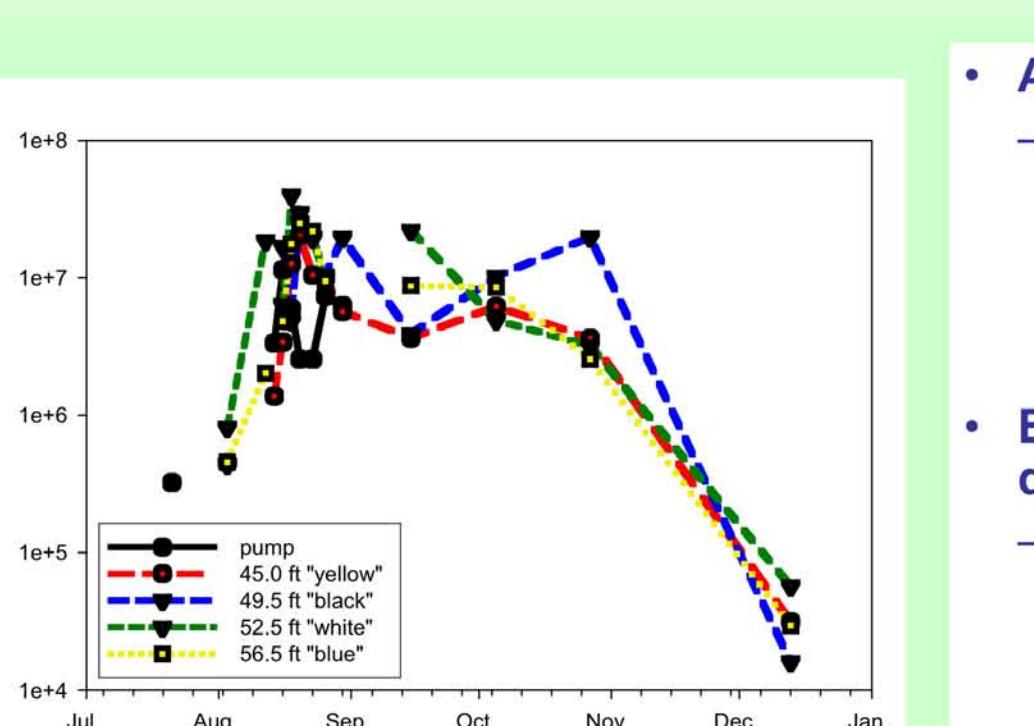
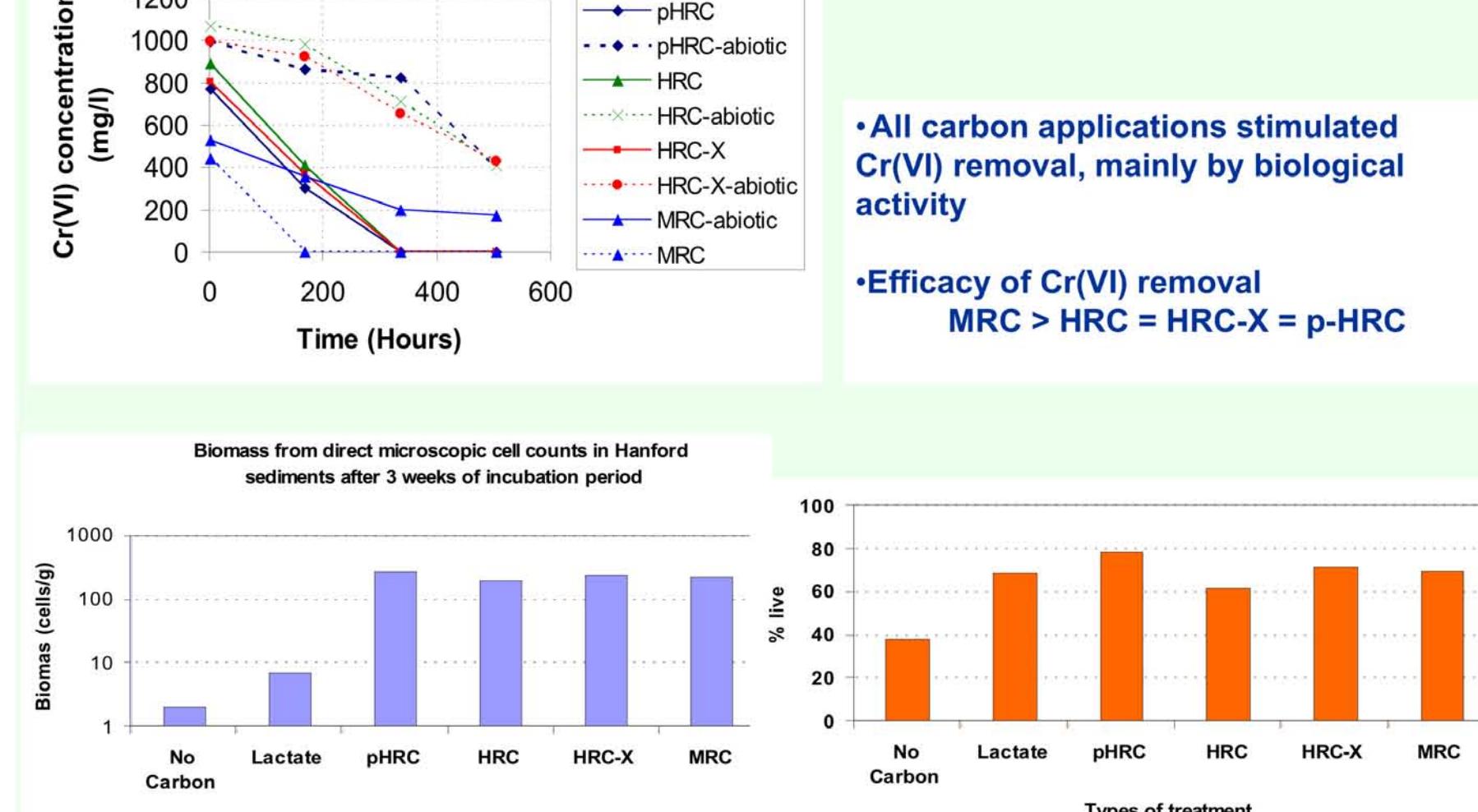
- Generates electron donors (lactate and hydrogen) for microbial production of reducing conditions to stimulate precipitation of Cr(III) solids
- Stimulates microbial reduction and production of species that can chemically reduce Cr(VI) to Cr(III) like Fe(II) and hydrogen sulfide.
- Causes the microbial population to remove the oxygen, nitrate, sulfate and other competing electron acceptors, thus, depressing the redox potential in the aquifer, affecting the transformation of Cr(VI) species to Cr(III) species, which are precipitated to precipitate on soil particle surfaces or colloids.

III. Microcosm Bench-Scale Study

Test Schematic

- 100 g Hanford sediment and 33 ml Hanford groundwater (from Well 699-96-43) amended with:
- Cr(VI) to 1000 ppb
 - Carbon equivalent to 0.4g C kg⁻¹ sediment (~1g HRC kg⁻¹)
 - Autoclaved controls

Decrease in Cr(VI), CO₂ and H₂ Concentration with Time as Affected by Different Treatment



Sequencing at JGI

1000+ clones

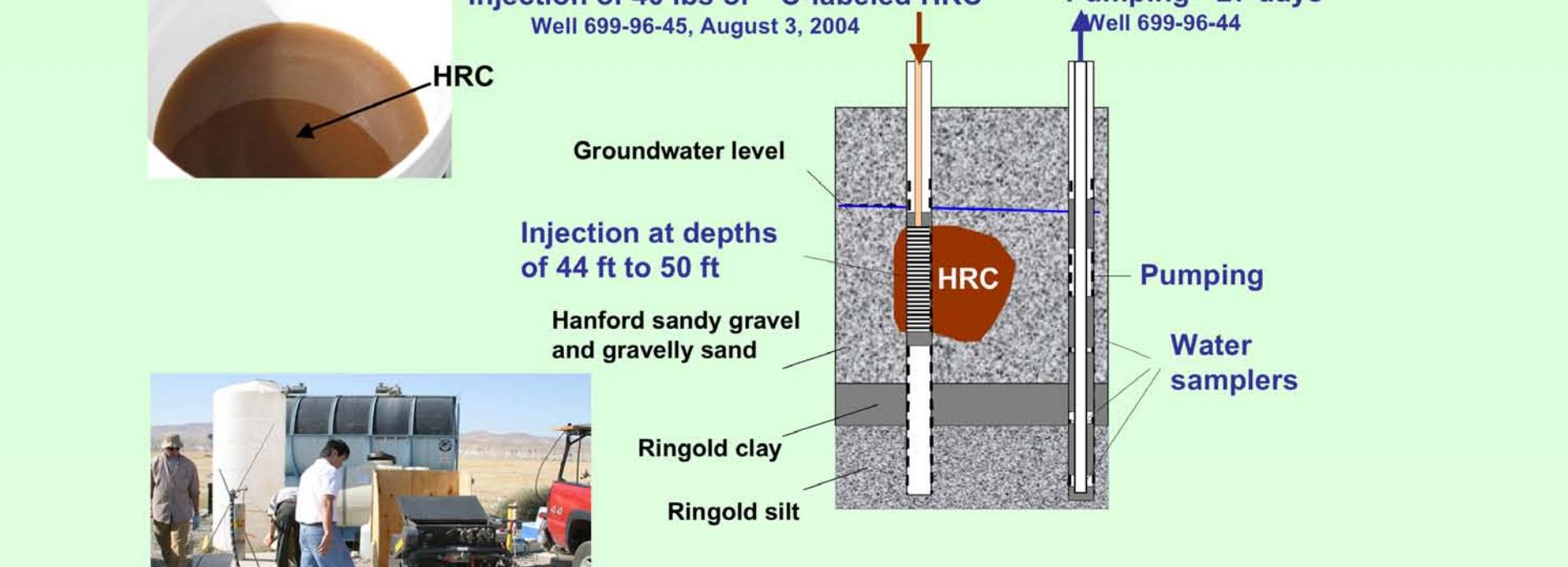
Phylogenetics

qPCR

Metagenomics?



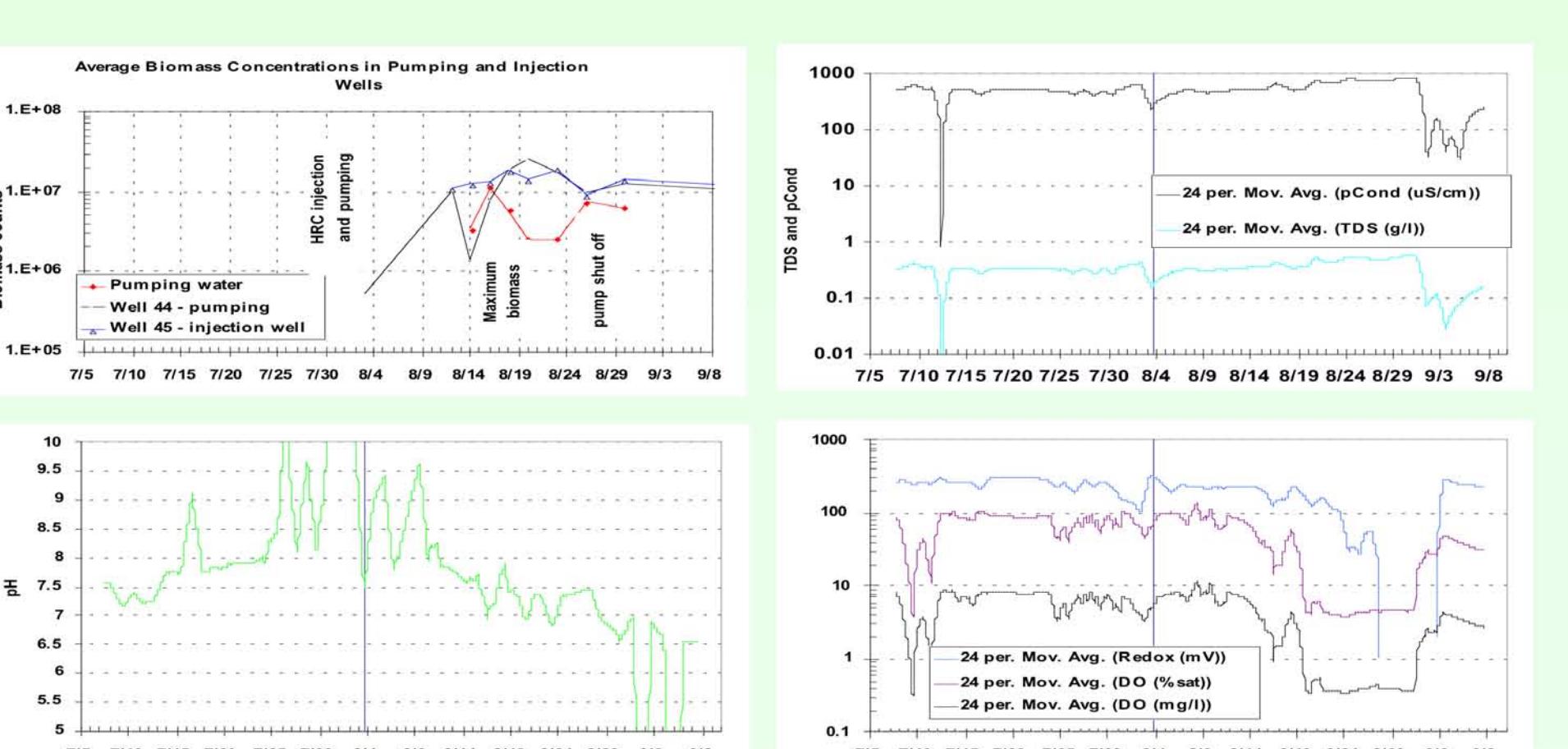
IV. Pilot Field Experiment of Groundwater Biostimulation Using HRC Injection



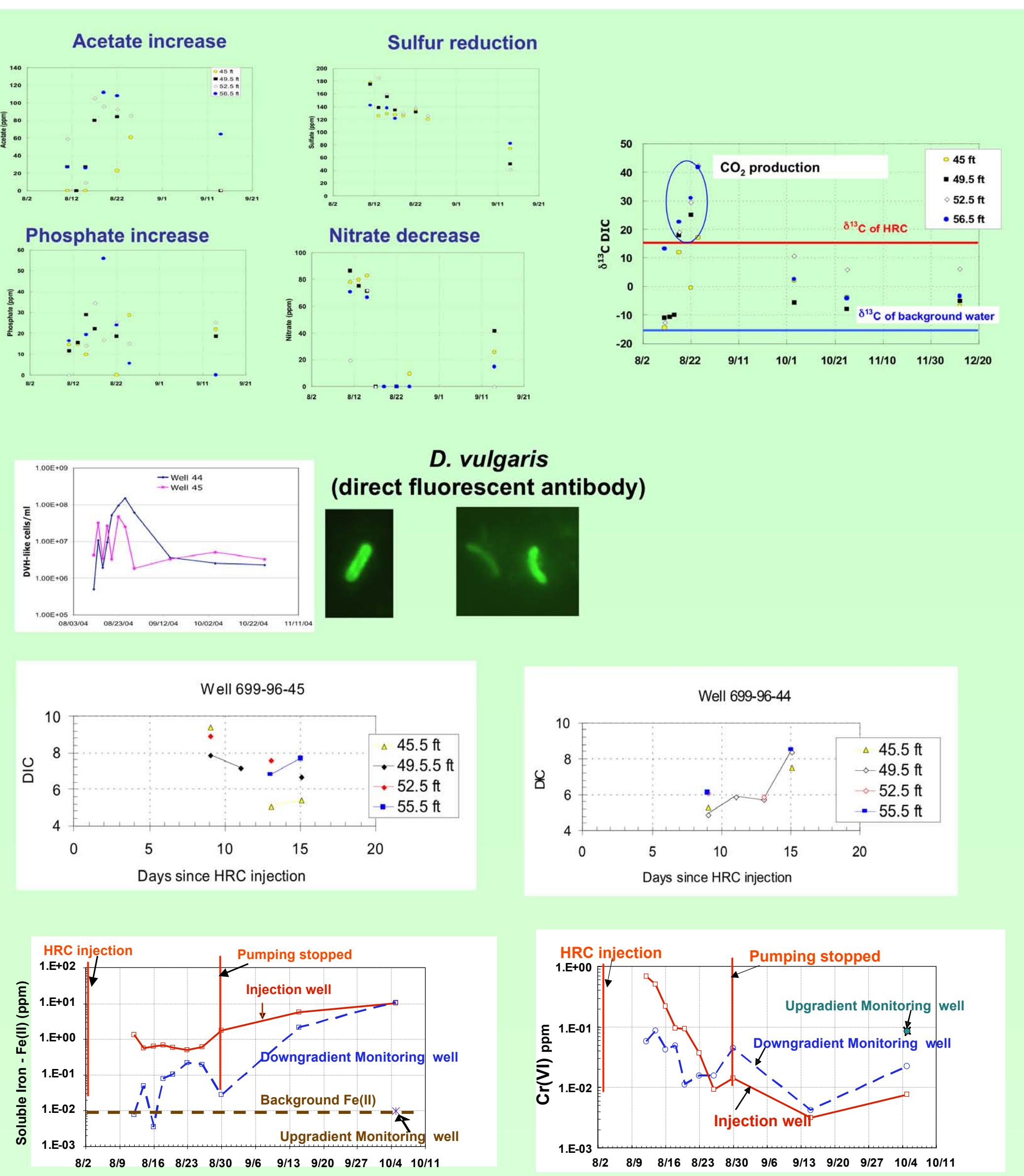
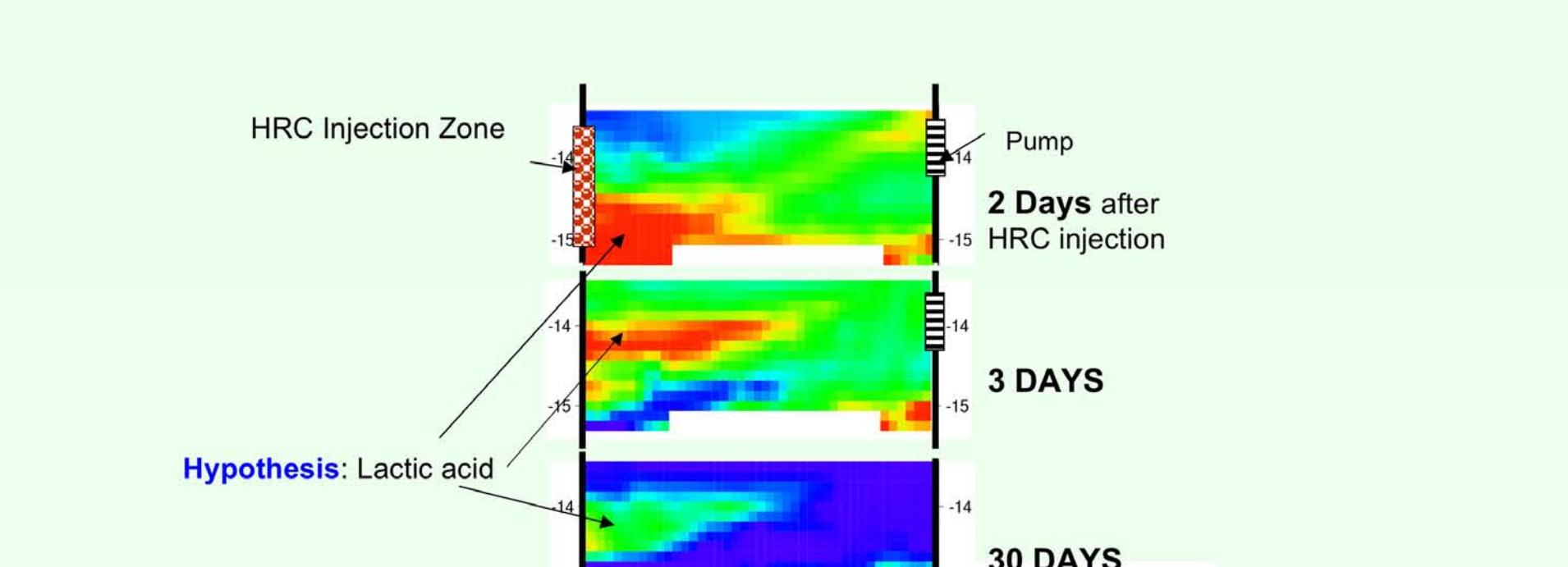
- All in 11 gal of water were used as a primer to fill the injection hose before the injection, dilute HRC, and as a chaser after the HRC injection.

- Br breakthrough occurred 7 days after the injection, and the maximum was reached 11 days after the injection.

- Microbial cell counts reached the maximum 13-17 days after the injection.



Post-HRC Injection Changes in Electrical Conductivity



V. Key Findings

- Several types of bacteria are present in the Hanford sediments, including *Arthrobacter*, *Oxalobacter*, *Sporomusa* and *Pseudomonas* species. Under background conditions, the total microbial population is <10⁵ cells g⁻¹.
 - Different types of HRC™ and metal remediation compound (MRC™) could generate biostimulation and increase biomass to >10⁸ cells g⁻¹, generate highly reducing conditions, and enhance Cr(VI) removal from the pore solution.
 - Pilot field-scale biostimulation of the groundwater shows microbial cell counts reached the maximum of 2×10⁷ cells g⁻¹ 13 to 17 days after the injection and continued to increase for the first 6 weeks, followed by the decrease in the microbial diversity.
 - DO dropped from 8.2 to 0.35 mg/l, redox potential from 240 to -130 mV, and pH from 8.9 to 6.5. DO and nitrate began to return to background concentrations two months after HRC injection, despite ground water bacterial densities remaining high (>10⁷ cells/ml).
 - Geophysical investigations show that HRC products (such as lactic acids) injected into groundwater can be detected using radar and seismic survey, and that even small variations in hydrogeological heterogeneity may influence the distribution of the amendment and its products.
 - δ¹³C ratios in dissolved inorganic carbon confirmed microbial metabolism of HRC. δ¹³C ratios remain above background values after 6 months. Increases in carbon isotope ratios of DIC in Well 44 are coincident with increases in bromide, chloride and acetate and decreases in nitrate. The source of chloride is likely from the HRC.
 - Hydrogen sulfide production was first observed after about 20 days post-injection, which corresponds with the enrichment of a *Desulfovibrio* species (sulfate reducer) identified using 16S rRNA microarray and monitored by direct fluorescent antibodies.
 - Cr(VI) concentrations in the monitoring and pumping wells decreased significantly and remained below up-gradient concentrations even after 6 months, when redox conditions and microbial densities had returned to background levels.
- Publications:
- Hazen, T.C., D. Joyner, S.Borglin, B.Faybishenko, J.Wan, T.Tokunaga, M.Conrad, C.Rios-Velazquez, J.Malave-Orengro, R.Martinez-Santiago, M.Firestone, E.Brodie, P.E. Long, A.Willet, and S.Koenigsberg, Functional Microbial Changes During Lactate-Stimulated Bioreduction of Cr(VI) to Cr(III) in Hanford 100H Sediments, Abstract submitted to the Fourth International Conference "Remediation of Chlorinated and Recalcitrant Compounds", May 24-27, 2004.
- Linde, N., S. Finsler, and S. Hubbard, Inversion of hydrological tracer test data using tomographic constraints, EOS Spring Supplement, Montreal, Canada, May 2004.
- Tokunaga T.K., Wan J.M., Firestone M.K., Hazen T.C., Olson K.R., Herman D.J., Sutton S.R., Lanzroti A. In situ reduction of chromium(VI) in heavily contaminated soils through organic carbon amendment, Journal of Environmental Quality, 32(2):1641-1649, 2003a.
- Tokunaga T.K., Wan J.M., Firestone M.K., Hazen T.C., Schwartz E., Firestone M.K., Sutton S.R., Newville M., Olson K.R., Lanzroti A., Rao W., Distribution of chromium contamination and microbial activity in soil aggregates, Journal of Environmental Quality, 32(2):541-549, 2003b.
- Tokunaga, T. K., J. Wan, M. K., Firestone, T. C., Hazen, E., Schwartz, S. R., Sutton, M., Newville, M. Chromium diffusion and reduction in soil aggregates. Environ. Sci. Technol., 35(16):1619-1624, 2001.
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